Using a Drone (UAV) to Determine the *Acer grandidentatum* (bigtooth maple) Density in a Relic, Isolated Community

O. W. Van Auken
Department of Biology, University of Texas at San Antonio, San Antonio, Texas
and

D. L. Taylor
Cisebsi Ltd. Co., Fair Oaks Ranch, Texas

ABSTRACT

Relic populations of *Acer grandidentatum* (bigtooth maple, Sapindaceae) are found in isolated, deep canyons in central Texas. These populations are challenging to get to and boundaries are hard to identify from ground level. Other woody species in these canyon communities include *Juniperus ashei* (ashe juniper), *Prunus serotina* (black cherry), *Quercus laceyi* (Lacey oak), *Q. buckleyi* (Texas red oak), *Tilia caroliniana* (Carolina basswood), *Aesculus pavia* (red buckeye) and other mostly deciduous species. The density of *A. grandidentatum* and associated species in a series of these isolated communities were measured using the quadrat procedure. However, this was a sample, not the whole community. The density of *A. grandidentatum* overstory trees based on the ground survey using the quadrat procedure was 788 ± 964 plants/ha and in the understory there were 176 ± 110 juvenile *A. grandidentatum* plants/ha. A UAV or drone was employed to survey the complete canyon community including the *A. grandidentatum* population that was under study. This was completed in the fall of 2016 when the deciduous plants were in full autumn colors so the limits of these deciduous communities would be more visible from the air. The boundaries of the *A. grandidentatum* communities in the canyon were digitally outlined on a computer and the total area was estimated. Total area of the *Acer* communities was 3.81 ha (9.41 ac). Using this area, the predicted number of *A. grandidentatum* overstory trees was 3,002 while the number of juveniles was 681 in this isolated, relic, canyon community. The total number of most other overstory and understory woody species present in these communities would also increase by a factor of 3.81. Published on-line www.phytologia.org *Phytologia 99(3): 208-220 (Aug 8, 2017)*. ISSN 030319430.

KEY WORDS: populations, central Texas, unmanned aircraft system, UAS, rare species, overstory, understory.

The use of drones, UAV's (unmanned aerial vehicles) or UAS's (unmanned aircraft systems) is a relatively new technology to assess and survey plant or animal species, including populations or communities difficult to approach, detect or observe, as well as identifying insect infestations, drought effects and inspecting areas with populations that are hard to reach. In addition, using a drone has minimal impact on sensitive habitat and causes little disturbance to easily agitated or hypersensitive species (Ogden 2013; Hodgson et al. 2016; Christie et al. 2016; Cruzan et al. 2016). Drones could be used to find and identify unreported communities and populations of relatively rare species.

Acer grandidentatum (bigtooth maple, Sapindaceae) populations in central Texas have been studied for several years. Juvenile plants are sensitive to herbivory (Nelson-Dickerson 2011; Nelson-Dickerson and Van Auken 2016) and they appear to be shade plants (Nelson-Dickerson and Van Auken 2017) having reduced CO_2 uptake in low light conditions, but not as low as sun plants in shade. In addition, their niche seems to be deep, sheltered, limestone canyons with some plants in these central Texas canyons establishing approximately 400 years ago (Van Auken et al. 2017). However, only population samples from these communities have been measured, never the entire communities.

Woodland and forest population dynamics are difficult to understand, probably because of the long lives of the woody species present. A glimpse of the past can be gained by looking at size or age distributions, but looking into the future is a guess. A favorite quote is "Prediction is very difficult, especially about the future.", Niels Bohr, Danish physicist, 1885-1962. Previously, size and age structure of several different species including central Texas *A. grandidentatum* populations were examined to try and determine potential success of the species in the future (Ryniker et al. 2006; Van Auken et al. 2007, 2017; Van Auken and Bush 2013). Most of the species examined turned out to be early successional species (shade intolerant) requiring a disturbance to continue in the same community in the future. *Acer grandidentatum* is however a shade tolerant woody plant, capable of growing in mature woodland or forest understories (Nelson-Dickerson and Van Auken 2017).

There are anecdotal reports indicating that *A. grandidentatum* populations in central Texas are not being replaced (BCNPSOT 2010; Heidemann 2011). There is some evidence that suggests high populations of white-tailed deer (*Odocoileus virginianus*) are a cause of lack of *A. grandidentatum* recruitment (Nelson-Dickerson and Van Auken 2016). But, this is not known for all populations of *A. grandidentatum* in central Texas and this could be a temporal or cyclic phenomenon, reoccurring at unknown, but long temporal intervals.

In addition, estimating population composition of low-density species, species with discontinuous distributions, or future populations of long-lived species has proved troublesome, time consuming and expensive. Use of drones could reduce the time and expense of studying populations or communities as indicated above.

PURPOSE

The purpose of this study was to determine the area covered and the number of overstory and understory *A. grandidentatum* plants in "Tin Cup Canyon", a steep, isolated, central Texas canyon community. To do this we used drone or UAV technology. With success, drone technology could be used in the remaining parts of the Albert and Bessie Kronkosky State Natural Area to determine the total area covered by *A. grandidentatum* and the number of plants present in the entire Natural Area.

METHODS

Previously, a ground level, quadrat survey of five adjacent, but isolated *A. grandidentatum* communities in the Edwards Plateau Physiographic region of central Texas was completed (Figure 1, approximately 29° 44' 25'' N, 98° 50' 18'' W, Van Auken et al. 2017). The communities are located in deep, isolated, limestone canyons (Figure 2) of the 1520 ha (=3757 ac) Albert and Bessie Kronkosky State Natural Area (=ABK throughout), specifically in the "Tin Cup Canyon" (Van Auken et al. 2017).

Domestic grazing was the main industry of the general area including the Natural Area, but in 1998 a 2.4 m high deer fence was constructed and domestic grazing was halted (Carpenter and Brandimarte 2014). The elevation of the study area is 484-614 m a. m. s. and canyon bottom *Acer grandidentatum* communities have relatively deep calcareous silty clay soil (Mollisols over limestone bedrock, SCS 1977). Mean annual temperature is approximately 18.3°C, with a range from near 0.7°C in January to 34.1°C in August, and is highly variable. Mean annual precipitation is 72.4 cm/year with very little in July and August and highly variable with May and September being wettest (World Climate 2011).

Density of overstory *A. grandidentatum* trees and six other species with the highest density found in these communities was determined and will be presented. However, the total area of each community in the previous study was not determined. In the current study the density previously calculated was used for the seven high density species present in the deciduous community (Van Auken et al. 2017). The area of each community was estimated based on a drone aerial survey, and the mean density of the five deciduous communities previously determined was used to calculate the number of each overstory and understory species in the canyon deciduous communities.

The canyon study areas were first surveyed by conducting a reconnaissance flyover in November 2014 as the canyon deciduous canopy started to change color. Field conditions and site accessibility allowed ground surveying the deciduous woodlands containing the *A. grandidentatum* woody plant population in five adjacent but separate canyon sites beginning in November 2015 and continuing through June of 2016 using the quadrat method (Van Auken et al. 2005).

The number of 25 m^2 quadrats varied in each of the *A. grandidentatum* communities due to site conditions and topography. Adequate sampling was determined by examining species and density stabilization curves but is not presented. There were a total of 223 quadrats or 0.56 ha sampled in the *Acer* communities. All plants greater than 137 cm in height and 3 cm basal diameter were considered trees and part of the overstory. They were identified (Correll and Johnston 1979; USDA 2016) and counted. Five 1 m^2 sub-quadrats were established in each of the 25 m^2 quadrats to measure understory woody plants (one in each corner and one near the center). All woody plants less than 137 cm in height and/or 3 cm basal diameter were identified and counted as seedlings or juveniles. Identity, density, relative density, basal area, and relative basal area were calculated for each overstory species and identity and density was determined for the understory species within each community (Van Auken et al. 2017). Next, means were determined, but only mean species density and relative density are presented here for overstory and understory woody species.

In order to visually distinguish the entire area of the *A. grandidentatum* community, we observed the change of color of the trees. At the point in time when the deciduous species colors could be easily distinguished from other species present the drone survey was started. Airborne Aerial Photography was engaged to fly a DJI Phantom 4 quadcopter (Figure 3) at an altitude of 96.3 m (=316 feet AGL [above ground level] from the point of liftoff) in an east – west pattern across the "Tin Cup Canyon" area of the ABK Preserve (Figure 4). Flight conditions were within the range allowed by a Texas Parks and Wildlife drone operating permit (issued to Justin Moore). This allowed orthoimagery coverage of the entire canyon area previously sampled using the quadrat method on the ground (Figure 5). Cloud cover was 100% reducing the possibility of shadow casts and image stitching errors. Airborne time was just under 12 minutes to cover 18 ha (= 46 acres at a resolution of 4.064 cm or 1.6 inches per pixel). The camera ISO was set at 400 and shutter speed at 1/240 sec.

The captured imagery was then uploaded to Drone Deploy for stitching and then exported as a georeferenced TIFF image. The TIFF was then imported to ArcGIS desktop software. Using the canopy color as a guide, the *A. grandidentatum* communities were outlined to create polygons (Figure 6). Area was calculated using the ArcGIS measurement tools on the resultant polygons. The ground sample areas were measured, then summed to get the actual total deciduous community area in ha, and was multiplied by the specific plant density in plants/ha to determine the number of plants of each species in the entire canyon deciduous woodland community.

RESULTS

The locations of the five deciduous woodland communities sampled in our previous study are identified on the drone photograph (Figure 6). The number of 25 m^2 quadrats examined in the "Tin Cup" deciduous woodland communities was 24-85, with an average of 44.6 quadrats/transect or community (Table 1). Total area sampled was 5,575 m^2 or 0.56 ha with an average area of 0.112 ha/transect or community. The area of the deciduous woodlands estimated from the drone photographs was 1,637-17,089 m^2 (Table 1). Total area of the deciduous woodlands was 38,070 m^2 or 3.81ha.

From the previous study, seven overstory species were found with high density or relative density including the highest that was *A. grandidentatum* (Table 2). Density of *A. grandidentatum* was 788 ± 965 plants/ha or 52% of the total community density of 1,343 ± 987 plants/ha. *Juniperus ashei* had the second highest relative density at 25%, with the other five major species found in these communities having relative densities between one and six percent (Table 2). The number of overstory *A. grandidentatum* plants or trees expected overall in these deciduous communities was 3,002 (Table 2). The number of most of the other species would be expected to increase by the same amount, 3.81 times, which is the total area of the deciduous communities based on the calculation from the drone pictures.

For the understory seven species were found in the previous study with fairly high density or relative density including *A. grandidentatum* (Table 3). Density of understory or juvenile *A. grandidentatum* plants was 176 ± 110 plants/ha or 13% of the total community understory density of 1,407 ± 987 plants/ha. This was the fourth highest relative density (Table 3). *Juniperus ashei* had the seventh highest relative density at 5%, with the other five major species found in these communities having equal or higher densities and relative densities (Table 3). The number of understory *A. grandidentatum* plants or juveniles expected overall in these deciduous communities was 671 (Table 3). The number of most of the other species would be expected to increase by the same amount, 3.81 times, which is the total area of the deciduous communities based on the calculation from the drone pictures.

DISCUSSION

After a literature review, this report seems to be the first study in Texas to determine plant community area using drone technology. It is also the first study to use community area determined from drone derived photographs and ArcGIS software to estimate the number of plants of certain species within a specific community. This unmanned aircraft technology has been used in other areas and in many types of studies including a wide range of applications in applied work and population surveys of both plants and animals (Ogden 2013; Hodgson et al. 2016; Christie et al. 2016; Cruzan et al. 2016).

Drones have been used to monitor insect pests in crops and forests (see Ogden 2013). They have been used to locate small mammal burros (pygmy rabbits) as well as following and counting sandhill crane populations. Animal populations difficult to access and count such as manatees, other marine mammals, as well as various nesting bird populations have been observed using drone technology. Others have used drones to try to reduce the illegal killing of large endangered animals. Plant ecological studies can be done with drones as well and can be similar to what has been done with animals (see Cruzan et al. 2016). However, the species or populations may not seem as spectacular. Habitat maps have been made with relatively small effort but with minimal habitat destruction, especially for marsh or wetland habitats. Drone aerial surveys can be done at various times of the growing season to discern species using seasonal phenology. Diseases can be followed using spectral analysis as can community disturbances and restoration.

Using unmanned aircraft or drones can reduce the high cost of field studies by 90 – 94% or by 10-16.7 times (Ogden 2013). There are suggestions that drone use increases collection efficiency, cost effectiveness and accuracy over ground methods (Hodgson et al. 2016). Regardless, drone or aircraft collected information must be ground-truthed. For the current study, drone flight time was 12 minutes to photograph 18 ha. It took a team of three approximately 30 days (90 man days) in the field to get to the study site in the canyon and count and measure the overstory and understory woody plants in 0.56 ha. These times do not consider man-hours working with the drone photographs or entering field data into the computer and calculating ecological parameters. However, it certainly suggests the efficiency of using drone collected data compared to ground based field work.

Size of native populations are basically unknown, thus it is not really possible to know the correctness or accuracy of a specific procedure to determine a specific population size. However, it is feasible to compare the variance of populations reported by different investigators using the same or different procedures. Lower variance has been reported for a number of population studies when comparable drone counts were examined (Hodgson et al. 2016). Standard deviation calculated for total density or individual species density was high in the current study, probably because of large size differences in the communities examined.

Different personnel have not been used to examine drone derived photographs or ArcGIS measurements to determine the area covered by the deciduous population or compared variance associated with these types of measurements, but this will be considered in the future. It is still difficult to determine the edge of the deciduous woodland community as can be noted by examining Figure 4. *Juniperus ashei* trees and some of the deciduous species inter-digitate at the edge of the upland *Juniperus* community and the deciduous woodland where *A. grandidentatum* is found. In addition, some of the deciduous species of the genus *Quercus* had apparently not changed colors when the current drone study was carried out. This potential error was minimized by drawing limiting lines through the middle of these inter-digitations.

In the future, drone technology will be fused with GIS remote sensing procedures to identify the species in these woodlands from each other to reduce variance and to better estimate population density. This procedure has been used in other studies and can certainly be used in these central Texas remote, relic populations.

ACKNOWLEDGEMENTS

We thank James Rice superintendent of the Albert and Bessie Kronkosky State Natural Area for permission to study isolated *Acer grandidentatum* communities in the Natural Area and for supplies needed for the study. Both James Rice and Tom Riordan helped us with transportation to get to the remote study sites. We thank Justin Moore (Airborne Aerial Photography) for furnishing and flying the drone for this project. In addition he took and supplied the photographs of the *A. grandidentatum* community and helped with interpretation. The authors also thank Julian Chavez for preparing the *A. grandidentatum* distribution map. Anne Adams, Mathew Grunstra and Vonnie Jackson read an earlier version of this manuscript and offered many helpful suggestions and corrections. Ted Ballard, systems librarian at the West Custer County Library in Westcliffe, Colorado was very helpful adjusting the number of dpi's for all of the figures.

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Table 1. Transect or community number, quadrats sampled, area sampled m^2 and ha, total deciduous community in m^2 estimated from drone photographs and the sum of the area sampled using the drone photographs of the deciduous community (m^2 and ha).

Transect number	Number of quadrats	Area (m^2) Sampled	Area (ha) Sampled	Area (m^2) estimated from drone photographs
1	44	1,100	0.11	1,637
2	34	850	0.09	7,137
3	36	900	0.09	7,324
4	85	2,125	0.21	17,089
5	24	600	0.06	4,883
Total	223	5,575	0.56	38,070 m^2 = 3.81 ha

Table 2. Overstory species names, mean density (number/ha) ± SD and relative density of seven highest density species found in a previous study of the deciduous woodland community and the number of plants of each species predicted in the total community using drone photographs (3.81 ha x density/ha of the species in the previous community study).

Scientific name	Density	Relative Density	Number Predicted
Acer grandidentatum	788 ± 965	52	3,002
Juniperus ashei	299 ± 195	25	1,139
Prunus serotina	76 ± 70	6	290
Quercus laceyi	58 ± 27	6	221
Aesculus pavia	32 ± 48	4	122
Tilia caroliniana	23 ± 51	1	88
Quercus buckleyi	18 ± 22	1	69
Other species (7)	49	5	187
TOTAL	1,343 ± 987	100	5,118

Table 3. Understory species scientific names, mean density (number/ha) ± SD, relative density of seven of the highest density species found in a previous study of the deciduous woodland community and the number of plants of each species predicted in the total community using drone photographs (3.81 ha x density/ha of the species in the previous community study).

Scientific name	Density	Relative Density	Number Predicted
Quercus buckleyi	289 ± 288	21	1,101
Prunus serotina	229 ± 201	16	872
Quercus laceyi	227 ± 223	16	865
Acer grandidentatum	176 ± 110	13	671
*Smilax bono-nox***	140 ± 113	10	533
Aesculus pavia	73 ± 76	5	278
Juniperus ashei	65 ± 33	5	248
Other species (15)	209	14	796
TOTAL	1,407 ± 987	100	5,364

**woody vine

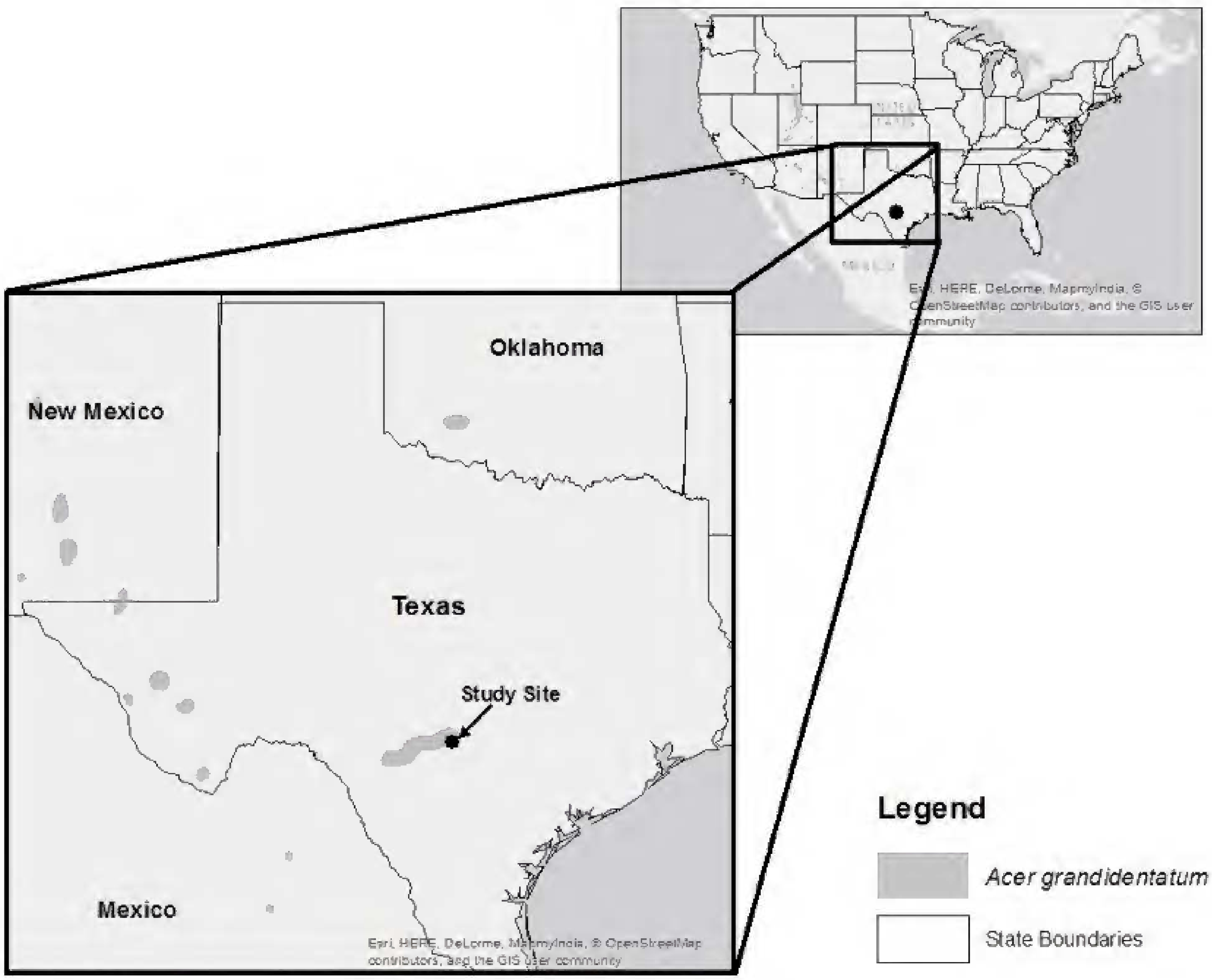

Figure 1. Distribution of *Acer grandidentatum* in Texas and western North America, with the blow-up showing the approximate location of the study site in central Texas. The arrow and the dot is the approximate location of the Albert and Bessie Kronkosky State Natural Area, in the Edwards Plateau Physiographic region of central Texas, approximately 29° 44’ 25’’ N, 98° 50’ 18’’ W.

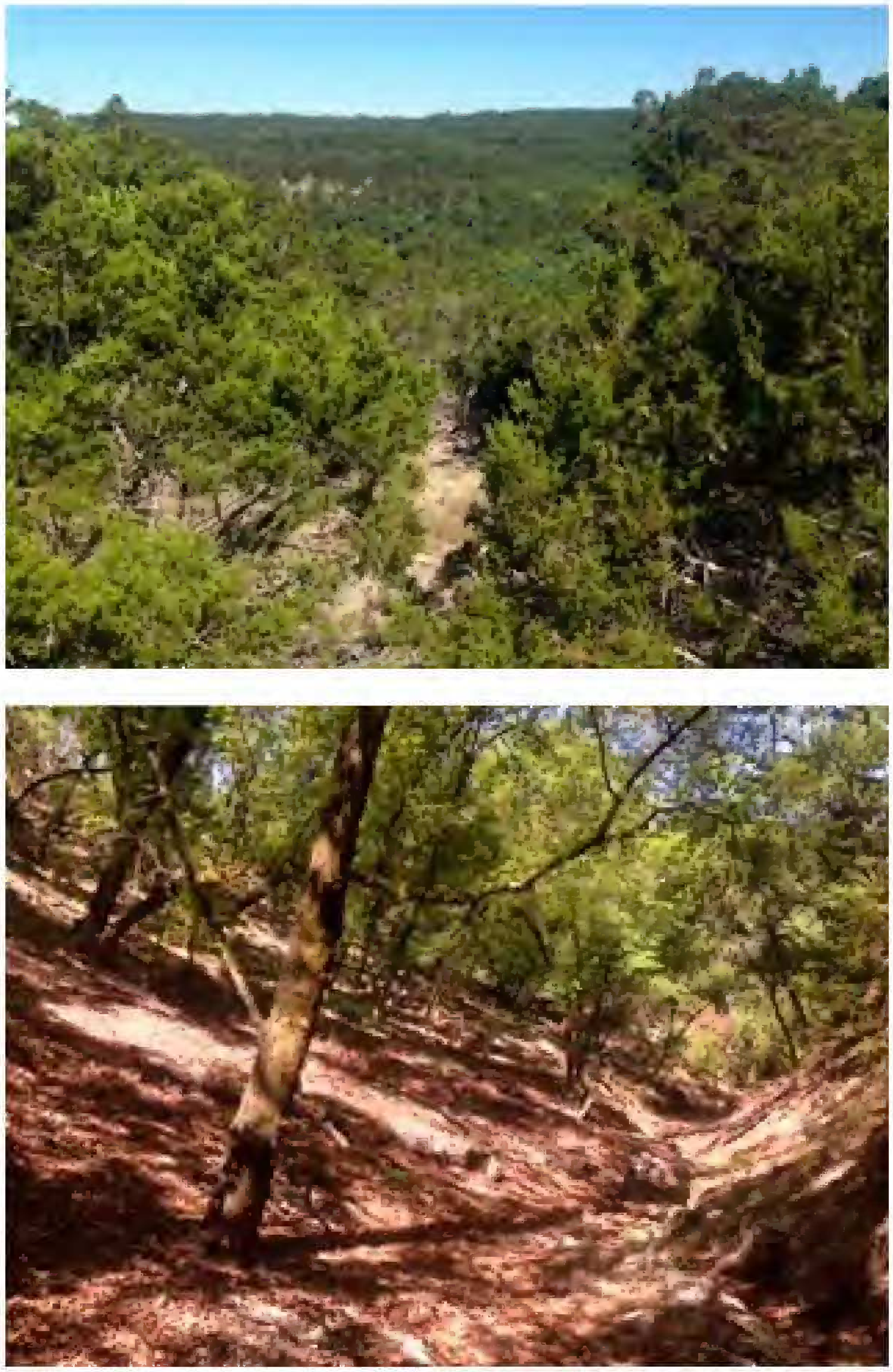

Figure 2. Photograph (upper) shows an overview of "Tin Cup Canyon" and the understory (lower) of several *Acer grandidentatum* trees in one of the community's surveyed. Note few or no understory juvenile woody plants.

Figure 3. Photograph of the drone (DJI Phantom 4 quadcopter) in the ground transportation (ATV, top left side) and on the landing pad prior to takeoff (top right). Middle photograph shows the crew and the ATV and the photograph was taken from the drone. The bottom photograph shows the landing pad (orange circle) taken from the drone with the authors and transportation on the hilltop adjacent to the "Tin Cup Canyon".

Figure 4. Oblique aerial view (upper photograph) of the study area, mostly "Tin Cup Canyon". Photograph was taken from the drone at an altitude of approximately 100 m on November 15, 2016 showing fall colors of the deciduous community in the canyon. The lower photograph is a close up view of the edge of the trees in the deciduous woodland. The arrow points out a *Juniperus ashei* tree.

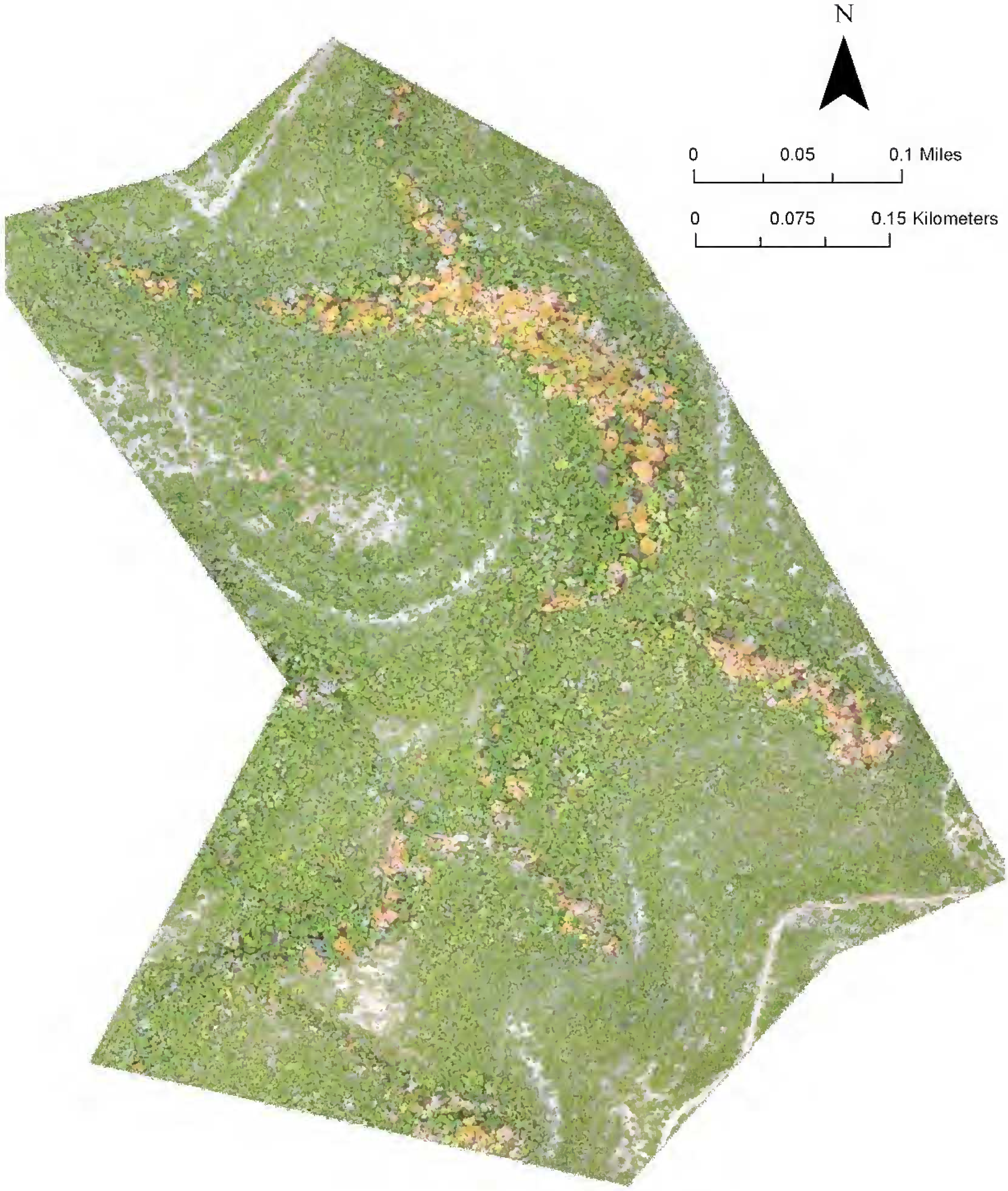

Figure 5. Aerial view of the overall study area from the drone. The deciduous communities are in fall color and at the bottom of "Tin Cup Canyon".

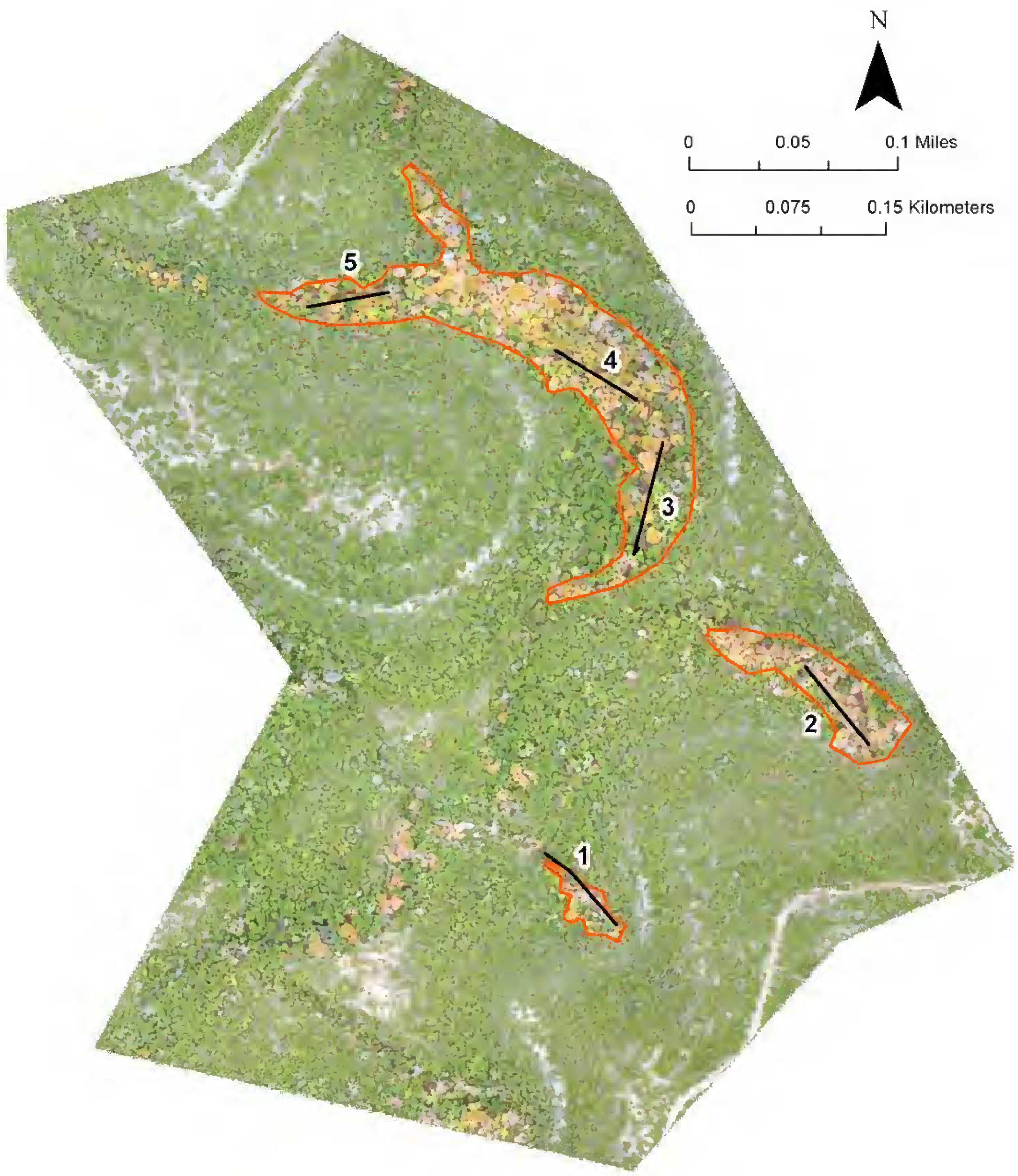

Figure 6. Study area from the drone at approximately 96.3 m (316 ft. AGL). Deciduous communities are outlined in orange with each transect in black and numbered.